Carrier separation effects in type-II Cd(Se,Te)/ZnTe self-assembled QDs

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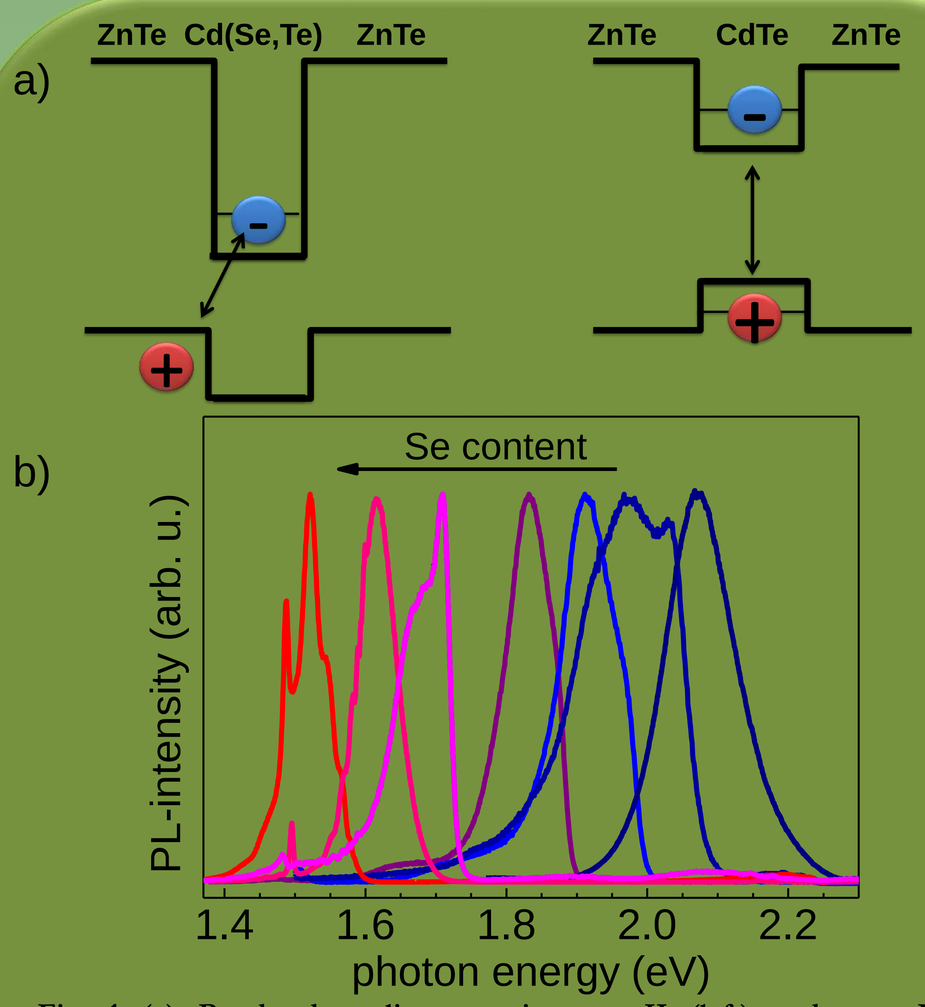

Fig. 1 (a) Band edge alignment in type II (left) and type I (right) heterostructures; arrow – optical transition (b) Photoluminescence from Cd(Se,Te)/ZnTe self-assembled quantum dots with various Se concentrations. The emission with the maximum at 2.1 eV comes from pure CdTe/ZnTe quantum dots. A considerable emission redshift is observed with increasing Se content inside the dots. Excitation is performed with 473 nm laser line and the temperature of the measurement is 6 K.

Introduction

Semiconductor heterostructures can be classified as type I or type II due to relative alignment of conduction and valence band edges.

In this work, we report on optical properties of self-assembled Cd(Se,Te)/ZnTe quantum dots (QDs) grown by molecular beam epitaxy. We demonstrate that the addition of Se induces type I to type II band alignment transition. Type II band alignment is demonstrated by the variation of the emission energy, increase of decay times and power dependence of the emission from individual quantum dots. Our results are recently published in Applied Physics Letters [1]

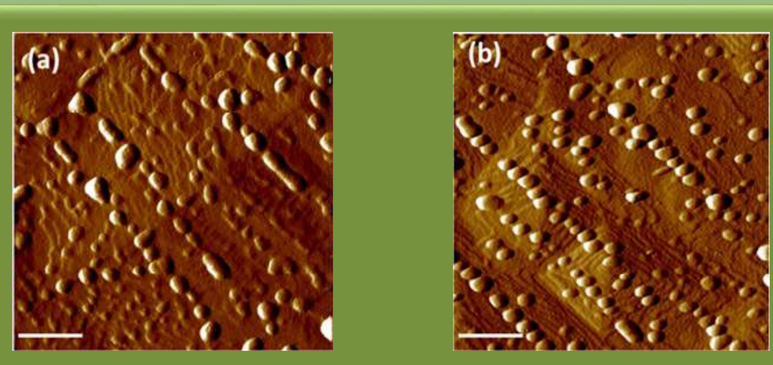

Fig. 3. Atomic Force Microscope images (amplitude error signal) from uncapped (a)CdTe (b) Cd(Se,Te) quantum dots with a quite large Se concentration corresponding to the full coverage of the central CdSe monolayer. No significant change of the averave QD size is observed after introduction of Se into the dots. The scale bars correspond to 200 nm.

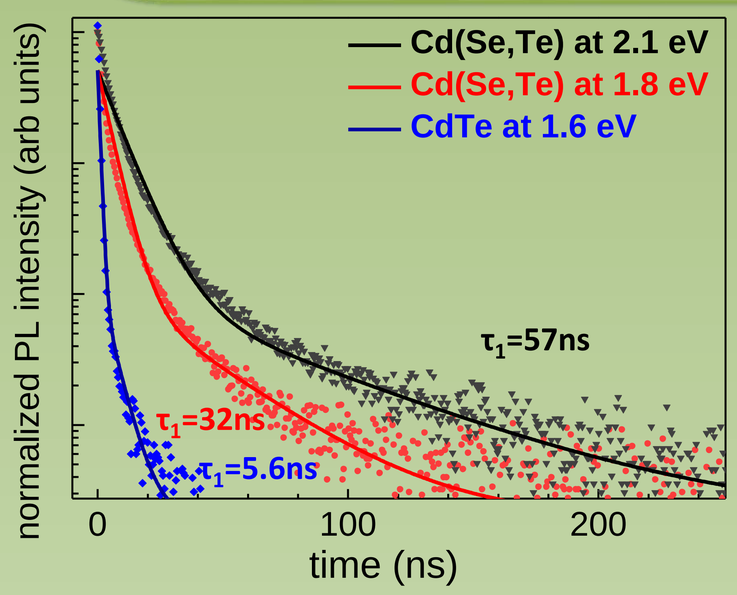

Fig. 2. Normalized time-resolved PL decays from CdTe/ZnTe and Cd(Se,Te)/ZnTe QDs with a moderate and high Se concentration emitting at 2.1 eV, 1.8 eV and 1.6 eV, respectively. An increase of the decay time with increasing Se concentration within the dots indicates type I to type II confinement type transition. The temperature of the measurement is 7 K and the excitation wavelength 400 nm; solid lines are fits with biexponential functions.

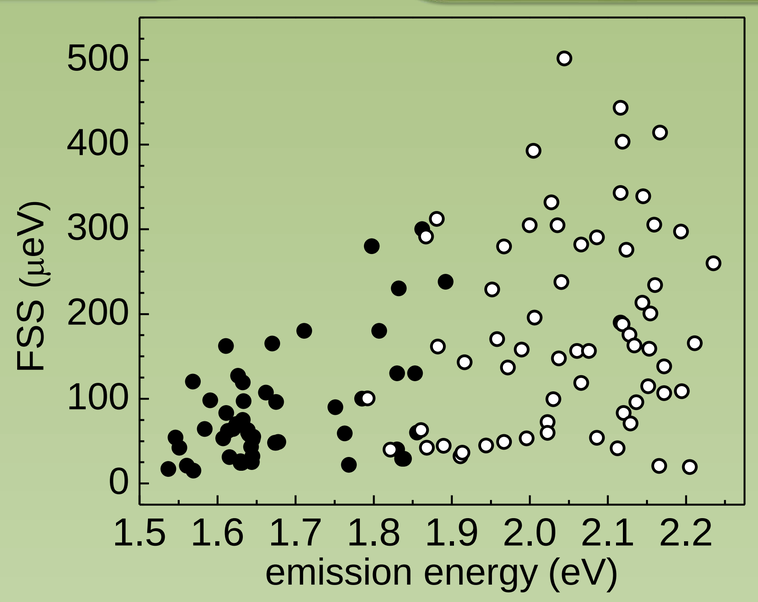

Fig. 4. Fine Structure Splitting (FSS) versus exciton emission energy plotted for several individual quantum dots. The increase of the average Se within the dots induces a decrease of the average FSS. Black points – Cd(Se,Te) QDs from several samples with various Se concentrations, white points – CdTe QDs[2].

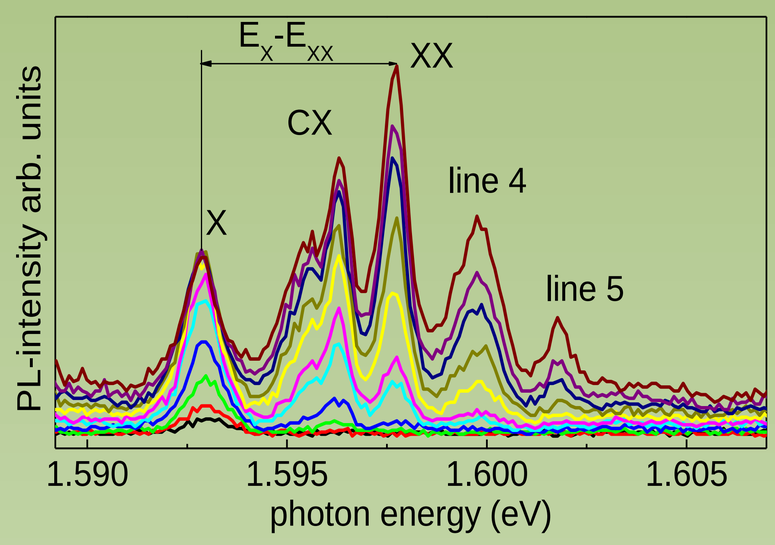

Fig. 5. Optical emission spectrum from an individual Cd(Se,Te)/ZnTe quantum dot at various excitation powers ranging from 300 μW to 30 mW. The lines are ascribed either to single exciton – X, charged exciton - CX and biexciton - XX emission. Antibinding character of biexciton is demonstrated.

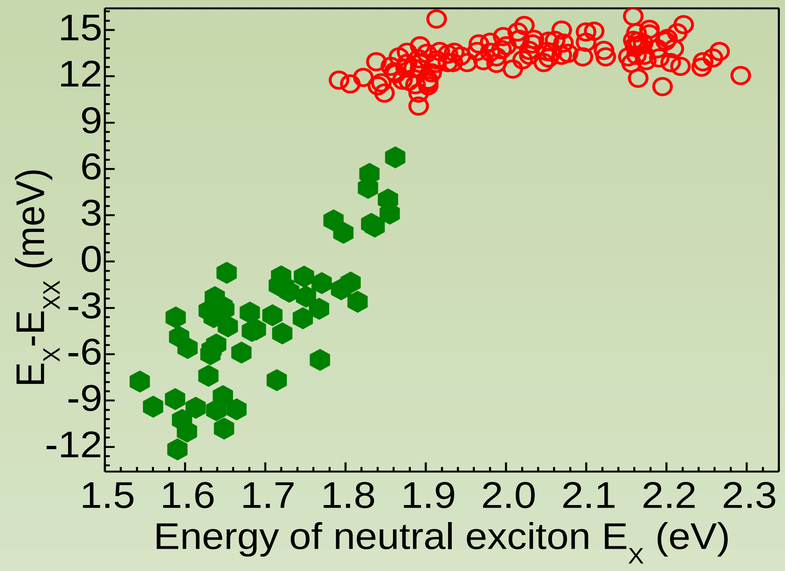

Fig. 6. The biexciton binding energy defined as X - XX spectral distance versus the X emission energy plotted for several individual quantum dots revealing a gradual change from binding to anibinding character of biexcitons. Green points - Cd(Se,Te) QDs from several samples with variuos Se concentrations, red circles – pure CdTe QDs[2]. The temperature of the measurement is always 7 K, and the excitation performed with 473 nm laser line.

Summary

- **Increasing Se concentration has a significant impact on the excitonic emission energy. Inserting just one CdSe monolayer into six monolayers thick CdTe QD-layer shifts energy emission by about 500 meV from 2.1 eV to 1.6 eV.**
- **Excitonic lifetime increases simultaneously by one order of magnitude, which can be interpreted in terms of type I to type II band alignment transition as effect of adding Se to CdTe QDs.**
- **Study of several individual QDs emission reveals that the biexciton binding energy (X-XX spectral distance) changes gradually its character from binding to antibinding with an increasing Se concentration.**
- **Fine structure splitting of the emission from individual QDs decreases with an increasing Se concentration within the Cd(Se,Te) dots**

All these effects can be explained in terms of a transition from type I to type II confinement.

References:

1. P. Baranowski, M. Szymura, G. Karczewski, A. Rodek, T. Kazimierczuk, P. Kossacki, T. Wojtowicz, J. Kossut, and P. Wojnar, Appl. Phys. Lett. **117**, 113101 (2020). DOI: 10.1063/5.0016326
2. T. Kazimierczuk, T. Smoleński, M. Goryca, Kłopotowski, P. Wojnar, K. Fronc, A. Golnik, M. Nawrocki, J.A. Gaj, and P. Kossacki, Phys. Rev. B - Condens. Matter Mater. Phys. **84**, 165319 (2011). DOI : 10.1103/PhysRevB.84.165319

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